IS 6134-7 (1981): Methods of Measurement of Electrical Characteristics of Microwave Tubes, Part VII: High-power Klystrons [LITD 4: Electron Tubes and Display Devices]

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VII HIGH-POWER KLYSTRONS

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VII HIGH-POWER KLYSTRONS

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VII HIGH-POWER KLYSTRONS

0. FOREWORD

0.1 This Indian Standard (Part VII) was adopted by the Indian Standards Institution on 23 June 1981, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard covers the methods of measurement of high-power klystrons.

0.3 The theoretical working of high-power klystrons has been given in Appendix A of this standard.

0.4 Methods of measurement of different types of microwave tubes are being covered in a series of standards consisting of the following individual parts:

Part I Common to all microwave tubes

Part II Oscillator tubes

Part III Amplifier tubes

Part IV Magnetrons

Part V Parasitic noise

Part VI Low-power oscillator klystrons

Part VII High-power klystrons

Part VIII Gas-filled microwave switching devices

Part IX Backward-wave oscillator tube — 'O' type

Part X Crossed-field amplifier tubes

0.5 While preparing this standard, assistance has been derived from IEC Pub 235-6 (1972) 'Measurement of the electrical properties of microwave

tubes: Part 6 High-power klystrons' issued by International Electrotechnical Commission.

0.6 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

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1. SCOPE

1.1 This standard (Part VII) describes the methods of measurement of electrical characteristics and related requirements and precautions applicable to high-power klystrons.

2. TERMINOLOGY

2.1 For the purpose of this standard, the terms and definitions given in IS : 1885 (Part IV/Sec 3)-1970† shall apply.

3. GENERAL MEASURING CONDITIONS AND PRECAUTIONS

3.1 General Precautions

3.1.1 Because of the very high voltages associated with high-power klystrons, it is essential to adhere scrupulously to national and local regulations regarding rf and X-radiation, high voltage and power, and other operating hazards to personnel.

3.1.2 It must be realized that the X-rays generated by a high-power klystron are many times more intense than those of a typical industrial X-ray tube. Consequently, any neglect of the precautions required by the manufacturer, or accidental omission of any part of the X-ray shielding, can cause immediate and lasting injury to the operator. This hazard is insidious, because the X-rays cannot be seen or immediately felt. It is also necessary to ensure the correct use of interlocks, earthing circuits, shielding arrangements and monitoring procedures.

3.1.3 Because of the large physical size of high-power klystrons, together with related magnets and cooling systems, the manufacturer's instructions regarding handling, packaging and storing should be strictly observed.

3.1.4 Some klystrons have beryllium oxide windows that must not be cleaned with abrasive materials, since beryllium oxide dust is dangerous when it is ingested, inhaled, or contaminates surface wounds.

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*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes.

3.1.5 High-power klystrons are usually operated with the tube body at ground potential, so that operating personnel are not subjected to the danger of high voltage on the microwave transmission line. Since the cathode is at a negative potential, all of the circuitry associated with the heater and control elements, if any, must therefore be suitably insulated from the high voltage.

NOTE — Because of the great amount of power available from high-power klystrons, it is essential that all microwave connections be thoroughly fastened to avoid radiation, which not only makes it difficult to make accurate measurements but may also be hazardous to personnel. The water load should be constructed carefully so as to avoid any pools of standing water, as such pools may be converted to steam with disastrous results.

3.2 Precautions to Prevent Damage During Measurements

3.2.1 In these high-power devices the energy of the electron beam is such that structures are easily melted if the beam impinges upon surfaces not specifically designed to withstand the heat. Thus, no beam power should be applied to the klystron until prescribed focusing conditions are maintained. Such focusing conditions optimize performance as well as conduct the beam to those structures which have been designed to cope with it.

3.2.2 In order to avoid damage to the tube by a defocussed beam, the manufacturer's instructions in regard to measurement procedure should be carefully observed in the measurement of small-signal gain or saturation power.

3.2.3 Care must be taken to ensure that the permissible electrode dissipation is not exceeded during measurements.

3.2.4 The klystron should be protected from improper operating conditions by suitable interlocks. It should not be operated with beam voltage 'ON' unless cooling and pressurizing circuits are operating and all necessary focussing potentials or fields are properly applied and the correct load is connected to the output. The stated maximum mismatch must not be exceeded, as serious damage may otherwise result. The user is advised to consult the manufacturer's instructions regarding sequence of application of voltages and currents. Because of large amounts of power that may be absorbed by portions of a klystron which have been designed for high-power service, it may be necessary to continue cooling service beyond the interruption of beam power. The possibility of protective circuit interruptions or power failure may, therefore, necessitate the storage of fluid under pressure. Because most liquid coolants expand upon freezing, it is necessary that cooling circuits be drained before a klystron is left inoperative in equipment.

3.2.5 All power indicators used in the tuning of a klystron should indicate only energy at fundamental frequencies, or false tuning will result from

harmonics present in the beam. This requirement is normally satisfied by the use of low-pass filters.

3.2.6 The frequent readjustment of focussing is recommended, so that the beam will not impinge upon surfaces not normally intended to receive appreciable quantities of electrons.

3.2.7 Poor focussing may result in low efficiency, melting of tube components, and unnecessary and excessive X-radiation.

3.2.8 An X-radiation survey should be made on installation of a high-power klystron. When excessive X-radiation is observed, a portion of the recommended shielding may have been omitted accidentally or the tube may be poorly tuned. In either case, the system should be shut down while the cause is determined and eliminated.

3.3 Ion Gauge

When provision is so made in the packaging, the ion gauge on the klystron should be connected to the terminals on the package, so that vacuum monitoring can be carried out in accordance with the manufacturer's instructions while the klystron remains packaged.

3.4 Handling

3.4.1 Protective covers over bushings, seals, waveguide output, and the protective shield over the cathode base must remain in place until the last possible moment before mounting. The manufacturer's instructions must be followed in removing the klystron from the package. Such instructions will generally designate the location of hoist connectors suitable for use in moving the tube separately from the package. Only the surfaces designated by the manufacturer shall support the weight of the klystron.

3.5 Mounting

3.5.1 Before the klystron is mounted in the measuring equipment, the socket, if used, shall be inspected for electrical and mechanical suitability and the cathode well, if present, shall be inspected for adequate voltage clearance, oil level and freedom from oil contamination by water or deterioration products. Only the oil recommended by the manufacturer shall be used, and air bubbles shall be removed.

3.5.2 Because bubbles may be introduced into the oil as a result of standing waves in the oil, caused by the periodic electric field, it may be necessary to provide baffles in the oil tank.

3.5.3 The mounting position and support point shall be as required by the manufacturer and excessive stress on the waveguide flanges shall be avoided.

3.5.4 After the klystron is mounted, the cooling and magnetic circuits shall be completed and inspected.

3.5.5 Precautions are necessary to avoid the effects of stray magnetic fields from nearby objects upon the tube performance.

3.6 External Cavities

3.6.1 When external cavities are required for measurement purposes, only standardized cavities and assemblies, as prescribed by the manufacturer, shall be used.

3.7 Electrode Voltages and Current

3.7.1 For measurement accuracy, the dc potentials to be applied to the klystron shall not have more than a stated ripple. The potentials shall be applied in the prescribed sequence, the stated delays being observed.

3.8 X-Radiation Hazards

3.8.1 Provision of **3.1** and **3.2** of this standard and **8.2** of IS : 6134 (Part I)-1978* shall apply.

3.9 RF Drive Conditions

3.9.1 The driver for a microwave amplifier shall be chosen with the required amplifier performance in view. The drive power and frequency shall be capable of smooth and continuous adjustment. There shall be sufficient decoupling so that the driver is not affected materially by klystron tuning adjustments. The drive system shall include incident and reflected power instrumentation, suitably filtered to avoid measurement of any harmonic energy.

3.10 Start-Up Conditions

3.10.1 The instructions given by the manufacturer for starting up the klystron should be rigorously followed. Such instructions should cover at least the following:

a) Before application of any tube potentials other than those of the ion gauge itself (where fitted) the ion gauge is operated for the prescribed time. Only after a satisfactory vacuum has been attained the other electrode potentials may be applied.

b) Cooling circuits are activated.

c) Heater power is applied.

*Methods of measurements of electrical characteristics of microwave tubes: Part I Common to all microwave tubes (*first revision*).

d) If the klystron is not fitted with permanent-magnet focussing, the focussing fields should be immediately applied and should be adjusted to the recommended levels throughout any thermal-drift period which ensues.

e) After the stated heater warm-up delay, the beam may be turned on in the prescribed manner. Usually it is helpful to operate the klystron without drive at 75 percent of normal high tension voltage while focussing is readjusted for minimum interception.

f) It is ensured that the X-radiation does not exceed permissible levels. Then it is retuned or such shielding is added as the tests indicate to be necessary.

g) The instructions should specifically indicate whether or not operation at full beam power without drive is permitted. If this is permitted and the klystron is not arcing, the beam input is increased to full power at a rate that does not produce persisting arcing. Then the step (h) is proceeded to. If it is not permitted, the tune-up conditions in **3.11** are proceeded to.

h) Radiation and beam transmission are rechecked and focussing is readjusted as needed. Then the provision of **3.11** are followed.

3.11 Tune-Up Conditions (Narrow-Band Operation)

3.11.1 The manufacturer shall provide tune-up instructions, which shall cover at least the following:

a) The penultimate cavity is tuned to a resonance frequency higher than the driving frequency.

b) With the klystron operating as in steps (g) and (h) of **3.10**, 6 dB less than normal driving power is applied.

c) The input cavity is adjusted for a minimum of reflection.

d) The focussing is adjusted for maximum output power and the radiation and beam transmission are checked.

e) Each successive cavity is tuned, except the penultimate cavity, for maximum output.

f) The focussing is readjusted for maximum output power and radiation and beam transmission are checked.

g) The penultimate cavity is tuned for maximum power and then slightly detuned on the high frequency side again. Focus and radiation are checked.

h) The full drive and beam power are applied and steps (c) to (f) are repeated. Alternatively, the output-cavity tuning and loading are adjusted until maximum power is obtained.

j) The penultimate cavity is tuned for maximum power.

k) Each cavity is retuned as required to obtain maximum output power and the focussing readjusted. Finally, radiation levels are checked.

4. RF MEASUREMENTS

4.1 Drive

4.1.1 The measurements shall be made in accordance with IS : 6134 (Part III)-1973*.

4.1.2 *Precaution* — In making these measurements, it is important to consult the manufacturer's instructions to determine whether or not the beam can be operated in the absence of rf drive at the appropriate frequency.

4.1.3 *Driving Power or Available Driving Power*

4.1.3.1 Unless otherwise specified, the power input to the amplifier tube shall be the fundamental frequency available power, measured by the use of directional couples devices having fundamental bandpass filters just ahead of the detectors.

These devices (including microwave filters used) shall be calibrated suitably, for example, by substitution method.

4.1.4 *Reflected Power or Input vswr*

4.1.4.1 Either of two means may be employed to make these measurements under stated conditions:

a) Reflected power may be measured using suitably filtered directional couplers, calibrated by substitution methods. Input vswr is calculated from the formula:

$$\text{vswr} = \frac{\sqrt{\text{Incident power} + \text{reflected power}}}{\sqrt{\text{Incident power} - \text{reflected power}}}$$

4.1.4.2 A Standing wave detector, suitably filtered and calibrated, may be used.

NOTE — Reflected power or vswr is a function of input cavity tuning, available drive power and beam current, and may be a function of tuning of the input cavity or other cavities or adjustment of focussing. These latter influences arise from feedback produced by returning electrons or from harmonic energy returned through the drift tube. Filters may be necessary to minimize the effects of the harmonics.

*Methods of measurements of electrical characteristics of microwave tubes: Part III Amplifier tubes.

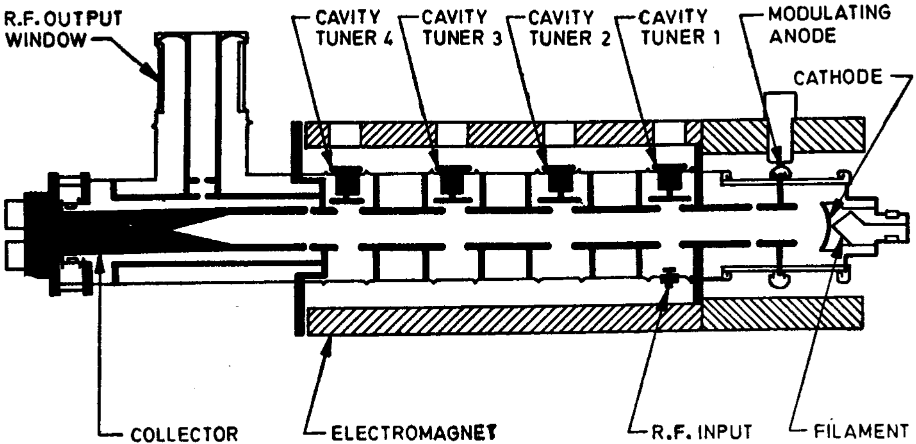

FIG. 1 KLYSTRON SCHEMATIC

4.2 Output Power — (*see* Fig. 2).

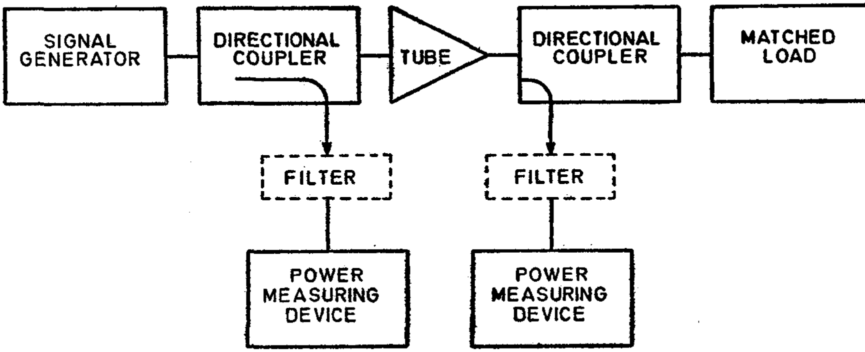

FIG. 2 BLOCK DIAGRAM OF A CIRCUIT FOR THE MEASUREMENT OF OUTPUT POWER

4.2.1 Provision of **10.1.3** of IS : 6134 (Part I)-1978* shall apply.

4.2.2 *Precaution* — *See* **4.1.2**.

4.3 Tuning

4.3.1 The method of measurement shall be in accordance with Appendix B.

NOTE — The klystron shall be operated under the stated conditions (including sweeping of the frequency of the driver, if necessary) to demonstrate the required performance when the klystron is suitably adjusted at each stated point in the tuning range.

4.4 Power Stability

4.4.1 The tube is adjusted for optimum performance under the stated conditions at thermal equilibrium. The adjustments are then maintained fixed for the measurement. The second set of stated conditions, usually removal of beam power only, is maintained for the stated period. Then the original conditions are restored and the tube is allowed to run until thermal equilibrium is established.

The shift in the stated variable is measured.

NOTE — This measurement is necessary because the thermal expansion of long structures may cause non-reproducible transients in tuning during warm-up.

*Methods of measurements of electrical characteristics of microwave tubes: Part I Common to all microwave tubes.

4.5 Mismatch Stability

4.5.1 Provisions of **10.3** of IS : 6134 (Part III)-1973* shall apply.

4.5.2 *Precautions*

a) To avoid damage to the klystron, the vswr must not exceed the stated maximum value.

b) The position of the mismatch device shall be so chosen as to avoid unwanted effects caused by harmonic frequencies or local rf fields within the waveguide near the mismatch device, but to avoid long-line effects the distance from the klystron shall be no greater than necessary.

4.6 Oscillator Measurements

4.6.1 *Temperature Coefficient of Frequency*

4.6.1.1 Provisions of **4.3** of IS : 6134 (Part III)-1973* shall apply.

4.6.2 *Spurious Mode*

4.6.2.1 Provisions of **5** of IS : 6134 (Part III)-1973* shall apply.

4.6.3 *Frequency Pushing* — It is a measure of the effect of electron beam susceptance on the frequency of the klystron. The tube is operated into a matched load. The test modulator is designed to produce alternate pulses with different energy levels, which results in two different rf spectra on the spectrum analyser dynamic pushing defined as:

Dynamic pushing $= \Delta f / \Delta i$ MHz/A

Static pushing is the changing of the average current drawn by the tube between two levels and thus noting the frequency

Static pushing $= f_1 - f_2 / I_1 - I_2$ MHz/A

4.6.4 *Frequency Pulling* — The tube is operated into a vswr of 1.5 : 1. The phase of 1.5 : 1 vswr load is varied over 360° and the maximum shift in frequency is the pulling figure of the klystron.

4.6.5 *Spectrum* (*Pulse Oscillators*)

4.6.5.1 The rf bandwidth and minor lobes are measured by means of an rf spectrum analyzer under the stated oscillation conditions end at the worst phase of the maximum permissible vswr unless otherwise stated in the manufacturer's specification.

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*Methods of measurement of electrical characteristics of microwave tubes: Part III Amplifier tubes.

a) *RF bandwidth* — This is measured at the stated level below the maximum of the major lobe. If any minor lobes are greater than the stated level of measurement, they are to be included in the measurement result.

b) *Minor lobes* — The differences in levels between the maximum of the major lobe and the maxima of the minor lobes are measured. The result is expressed as a ratio of power, or a difference in dB between the major lobe and the largest minor lobe.

4.7 Amplifier Measurements

4.7.1 *Available Power Gain*

4.7.1.1 Provisions of **4.2** of IS : 6134 (Part III)-1973* shall apply.

4.7.2 *Small Signal Gain*

4.7.2.1 Provisions of **4.3** of IS : 6134 (Part III)-1973* shall apply.

4.7.3 *Saturation Gain*

4.7.3.1 Provisions of **6.2** of IS : 6134 (Part III)-1973* shall apply.

4.7.3.2 *Precautions*

a) The tuning must not be adjusted to the maximum small-signal gain (synchronous gain) condition unless this condition is specifically permitted by the manufacturer's instructions.

b) The signal source should have a negligible harmonic content and should be sufficiently well matched, so that no reflections of harmonic power take place in the input line.

c) The filters should preferably not reflect harmonic power, but should absorb it as completely as possible.

4.7.4 *Instantaneous Bandwidth* — *See* Fig. 3.

4.7.4.1 Provisions of **5.1** of IS : 6134 (Part III)-1973* shall apply.

4.7.4.2 *Precautions*

a) The available driving power shall not vary by more than a stated fraction (usually ± 0.5 dB) in the swept frequency interval.

b) The sweeping frequency shall be much lower than the bandwidth of the tube and ratio amplifier, but high enough to exclude any thermal drift effects.

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*Methods of measurements of electrical charactertistics of microwave tubes: Part III Amplifier tubes.

c) Directional couplers and detectors shall have characteristics that are matched in the swept frequency interval.

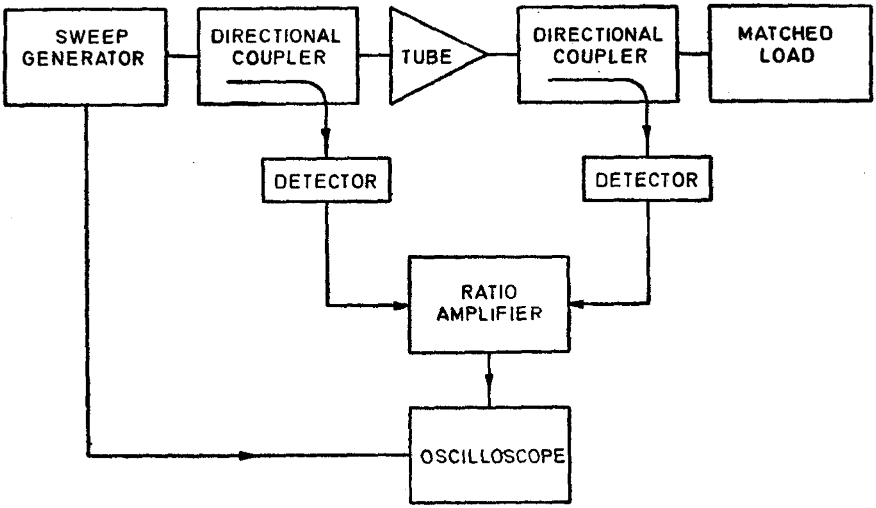

FIG. 3 BLOCK DIAGRAM OF A CIRCUIT FOR THE MEASUREMENT OF VARIATION OF GAIN WITH FREQUENCY

4.7.5 *Phase Sensitivity to Voltage or Current*

4.7.5.1 Provisions of **9** of IS : 6134 (Part III)-1973* shall apply.

4.7.6 *Harmonic Output Power*

4.7.6.1 Provisions of **6.3** of IS : 6134 (Part III)-1973* shall apply.

4.7.7 *Noise Figure* — Noise figure of an amplifier is a measure of the iegredation of the signal-to-noise ratio as the signal passes through the mplifier and is defined as:

$$N.F. = \frac{(S/N) \quad \text{input}}{(S/N) \quad \text{output}}$$

The noise figure of a high power klystron amplifier may be measured y the method whose schematic diagram is given in Fig. 1.

Apply normal operating voltages to the tube, observing the recommen-ıed precautions, with the input part of the tube terminated in matched load.

*Methods of measurements of electrical characteristics of microwave tubes: Part III nplifier tubes.

Note the output power meter reading and the attenuator setting. Increase the calibrated attenuator setting by 3 dB. Apply the rf drive necessary to restore the output power meter reading to the previous reading. Then the noise figure of the tube is given by

$$NF_{\mathrm{dB}} = 114 - S - B$$

where

B = 10 log (bandwidth in MHz of filter or the tube whichever is lower).

S = Power input from the calibrated signal source in dBm.

4.7.7.1 *Precautions*

a) Noise power from the tube at the detector input of the power meter shall be much greater than the intrinsic detected noise. This may be observed by noise power level with the tube being switched on and off. For reasonable accuracy, a 10 dB difference must be maintained.

b) The signal source shall present the same source impedance for which the amplifier is designed.

c) The signal source must be matched to the tube input both in ON and OFF conditions.

d) Spurious oscillations shall be avoided during the measurement.

APPENDIX A

(*Clause* 0·3)

THEORETICAL WORKING OF HIGH-POWER KLYSTRONS

A-1. THEORY

A-1.1 A high-power klystron is an electron tube in which a high-density electron beam traverses a sequence of non-intercepting gaps; these gaps act upon the beam to produce velocity variations which, after a suitable drift-period, cause density variations. Power can be extracted by provision of suitable impedance at the output gap. The beam is formed by an electron-emitting element in conjunction with fields derived from the accelerating

electrode, the focussing anode or the modulating anode, as modified by the effects of grid structures, if any are used.

A-1.2 The beam is confined by magnetic or electrostatic focussing means to prevent its expansion because of the high space-charge force acting within the beam. Such expansion would often result in low beam transmission. Alternatively, at a fixed power level, it is possible to use gap structures consistent with beam spread. Thus, beam transmission can be made acceptable. However, efficiency and amplifier gain may suffer because of the lower value of gap-coupling coefficient which results.

A-1.3 The use of a control grid in high-power klystrons is not common, because of the difficulties that may arise from grid emission. More commonly, focussing anodes are used to provide vernier control of beam parameters. For full modulation of the beam, a modulating anode is placed between the anode and the cathode to shield the cathode from anode fields and thus permit the beam current to be adjusted from zero to full values.

A-1.4 The beam first traverses an input gap excited at the driving frequency; the driving-frequency fields, coupling with the beam, produce variations in velocity. The beam then enters a suitable drift space where the overtaking of slower electrons by faster electrons results in the formation of a bunched (density modulated) beam. In addition to driving-frequency components, a very large number of harmonic components are present in the beam. The velocity of individual electrons may be further modified by subsequent passage through a sequence of additional gaps coupled to cavities that are excited by the electron beam at the driving frequency. By appropriate tuning of the resonant cavity attached to each gap (establishment of a suitable impedance), the bunches may be made so sharp as to modulate fully the beam at the driving frequency. The several intermediate gaps between the input and output gaps also increase gain by thoroughly bunching the beam before it enters the output gap. The cavities associated with these gaps can be carefully tuned off resonance to produce greater efficiency and bandwidth. In this way, high gain with bandwidth up to 10 percent can be achieved. When the bunched beam traverses the output gap, which is provided with a suitable impedance at the desired output frequency (fundamental or harmonic), power is extracted from the beam.

A-1.5 High-power klystrons use cavity-type reasonant circuits to couple to, and act upon, the electron beam. In some tubes, called integral-cavity klystrons, the cavities are part of the vacuum envelope. When the cavity is not completely within the vacuum envelope, a ceramic seal isolates that portion of the cavity which is within the envelope from the rest of the cavity. In either case, cavities can be tuned by appropriate deformation of the electromagnetic fields of the cavity. A general schematic cross-section view of an integral cavity tube is shown in Fig. 1. The user should refer to the manufacturer's instructions for details.

A-1.6 Power oscillator klystrons use the same type of interaction, but are constructed with feedback means to produce oscillations.

APPENDIX B

(*Clause* 4.3.1)

MEASUREMENTS FOR TUNING

B-1. FREQUENCY TUNING RANGE

B-1.1 This is obtained by measuring the characteristics of power output versus frequency. It is preferable that the required frequency range be obtained by the use of a single oscillatory mode. However, where a change of mode is permissible, this change shall not be considered as constituting a discontinuity of frequency tuning range.

B-2. TUNING SENSITIVITY (MECHANICAL OR ELECTRONIC)

B-2.1 The tuning sensitivity may be obtained from a measurement of frequency change with stated variation of the tuning control (mechanical or electronic) or alternatively, as a measurement of tuning control variation for a stated frequency change.

B-2.2 As the tuning sensitivity is not necessarily uniform over the required tuning range, it is recommended that an indication be given as to which part of the range is used in making the measurement, for example, a stated frequency spread centred at the half-power point over the linear range or in the small-signal range.

B-3. TUNER TORQUE

B-3.1 The tuner torque is measured at the required temperature under cold or operating conditions over the required tuning range by any suitable means. Measurements of starting, running and stop torque may be made.

B-3.1.1 *Precautions* — The rated maximum stop torque or force, including inertia forces, beyond which the parts of the tuning mechanism may sustain damage, must not be exceeded.

B-4. ELECTRONIC TUNING NON-LINEARITY

B-4.1 For this measurement, the frequency of oscillation is varied electronically over a small amplitude (for example, approximately 4 percent of the modulation range) and the frequency deviation is measured by means of a suitable fm receiver (or spectrum analyzer). The oscillation frequency is slowly swept by varying the direct voltage to the frequency controlling electrode while the small superimposed modulating voltage is maintained constant. The deviation at the centre frequency S_0 and the maximum change in frequency deviation $\triangle S$ occurring over the swept range are noted. The ratio $\frac{\triangle S}{S_0}$ is a measure of the electronic tuning non-linearity.

B-5. ELECTRONIC TUNING RATE OR TUNING SPEED

B-5.1 A periodic signal of stated amplitude is applied to the tuning control and the frequency excursion of the device is measured, either (1) over a stated portion of the duration of one tuning cycle, or (2) over a complete tuning cycle.

B-5.2 The tuning rate can then be expressed in two ways: (1) from the quotient of frequency excursion by the stated period of time, and (2) from the product of the total frequency excursion and the sweeping frequency (defined as the number of sweeps per second of the tuning control).

B-5.3 The two results may differ substantially.

B-5.4 At the stated amplitude, the sweeping frequency is slowly varied during the course of the measurement to determine the frequency at which the reduction of excursion or failure to tune takes place. The maximum tuning rate is determined from this frequency.

B-6. TUNING DISCONTINUITIES

B-6.1 In measuring tuning discontinuities, the frequency or power is measured over the frequency tuning range with an instrument of suitable resolution or precision. An abrupt change greater than a stated value shall be considered a discontinuity.

B-7. HYSTERESIS

B-7.1 This may be caused by either the mechanical properties of the tuning control itself, or by the electrical characteristics of the tube being measured.

B-7.2 If hysteresis is present in the measurements of tuning sensitivity or range, a separate measurement shall be made for each direction of variation of the tuning control and, if these results are in substantial agreement, either result may be quoted. If the results are not in agreement, the direction of variation shall be stated.

B-8. MECHANICAL TUNING HYSTERESIS

B-8.1 The tube shall be operated under stated conditions at the reference frequency. The mechanical tuner is cycled as required over the complete frequency tuning range, then returned to the original mechanical setting point, and the frequency measured. Movement of the tuner spindle is then continued in the same direction of the end of the range, after which the tuner is again returned to the original mechanical setting point, at which a second measurement of frequency is made. The mechanical tuning hysteresis is expressed as the difference between these two frequencies.

B-9. ELECTRONIC TUNING HYSTERESIS

B-9.1 The tube is operated under stated conditions at the reference frequency. The electronic tuning control voltage is varied by the application of a suitable alternating sweep voltage of stated amplitude and frequency.

B-10. POWER HYSTERESIS

B-10.1 The output power of the tube is measured as a function of the electronic tuning control voltage, the power obtained as the voltage is increased being compared with the power obtained as the voltage is decreased.

B-10.1.1 *Degree of Power Hysteresis* — This may be measured in two ways as follows:

a) The ratio of (1) the maximum degree of power hysteresis expressed, as a difference, within a stated swept range to (2) the maximum power within that swept range, the result being expressed as a percentage, or

b) The ratio of (1) the highest power at which a stated degree of power hysteresis is reached as hysteresis increases to (2) the maximum power within the swept range. The result is expressed as a percentage or in dB.

B-10.1.2 *Range of Power Hysteresis* — This is expressed as the ratio of (1) the electronic tuning voltage range over which a stated degree of power hysteresis is exceeded to (2) a stated part of the sweep voltage range (for example, in reflex klystrons, the voltage range which provides oscillation over the full mode; in backward wave oscillators, the voltage range required for tuning between stated frequencies). The result is expressed as a percentage.

B-11. FREQUENCY HYSTERESIS

B-11.1 The frequency of oscillation of the tube is examined as a function of the electronic tuning control voltage, the frequency obtained as the voltage

is increased, being compared with the frequency obtained as the voltage is decreased.

B-11.1.1 *Degree of Frequency Hysteresis* — This is measured as the absolute value of the difference between (1) the frequency obtained at a stated value of voltage as the voltage is increased through this value, and (2) the frequency obtained at the same value of voltage as the voltage is decreased through this value, the result being expressed in frequency units.

B-11.1.2 *Range of the Frequency Hysteresis* — This is measured as the ratio of (1) the electronic tuning voltage range over which a stated degree of frequency hysteresis is exceeded to (2) a stated part of the sweep voltage range, the result being expressed as a percentage.

B-12. TUNER STOP TORQUE OR FORCE

B-12.1 The tuning control is tuned against an end stop. After a prescribed torque has been applied under stated conditions, no degradation of tuning control performance shall have occurred.

B-12.2 The measurement is repeated for each stop in the tuning system.

B-12.2.1 *Precautions* — Impact against the stop must be avoided.